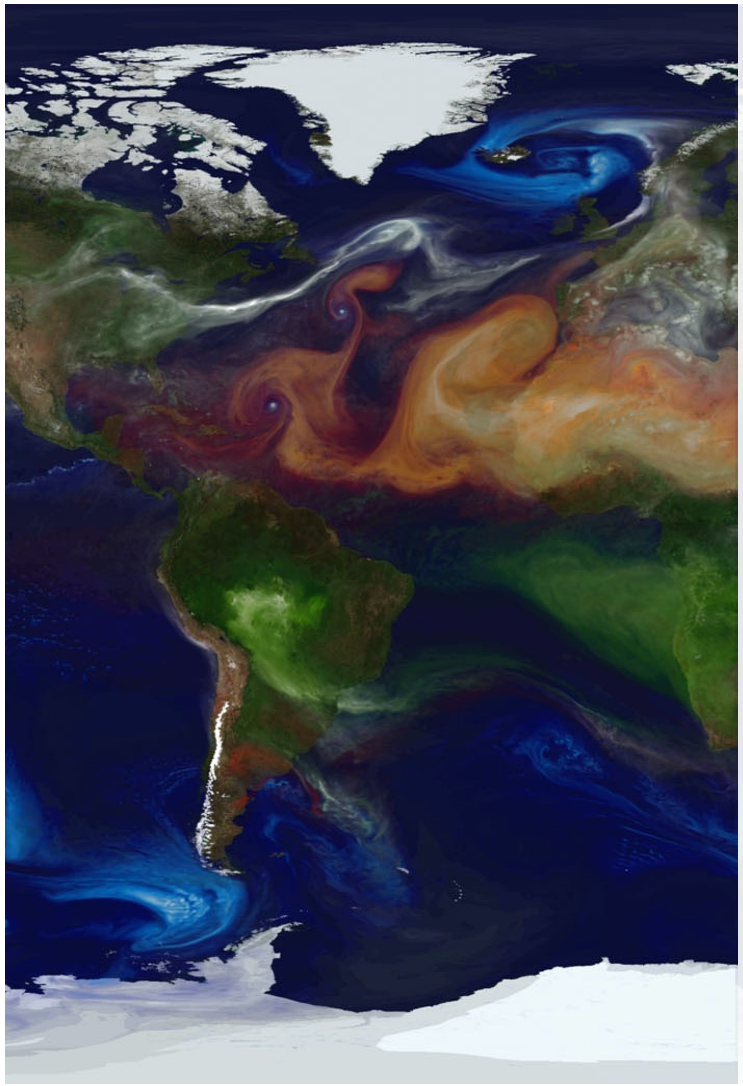


Plans and progress towards GMAO's next retrospective analysis products GEOS-R21C and GEOS-IT

Amal El Akkraoui[a,b]

On behalf of GMAO reanalysis team

[a]GMAO, Earth Sciences Division, Sciences and Exploration Directorate, NASA GSFC.

[b]Science Systems and Applications, Inc. (SSAI)

CERES-Libera Science Theme Meeting, May 2021

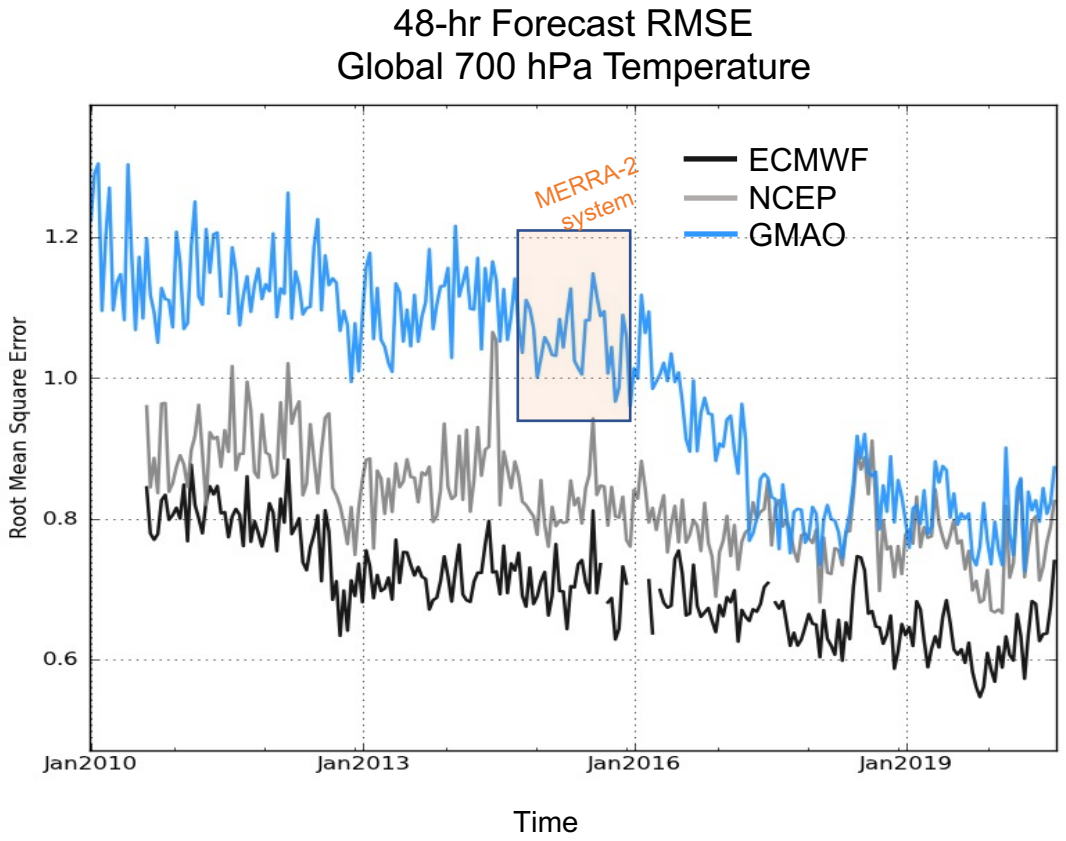
The GMAO is preparing to produce two retrospective products bridging the gap from NASA's EOS to the post-EOS observations:

- **GEOS-IT** for use by NASA instrument teams
- **GEOS-R21C** a retrospective analysis for the 21st century for reanalysis research applications.

Reasons to update retrospective analysis products

- Model and DAS developments lead to improvements in moisture, temperature, land surface fields.

Long-Term Improvements of Forecast Skill

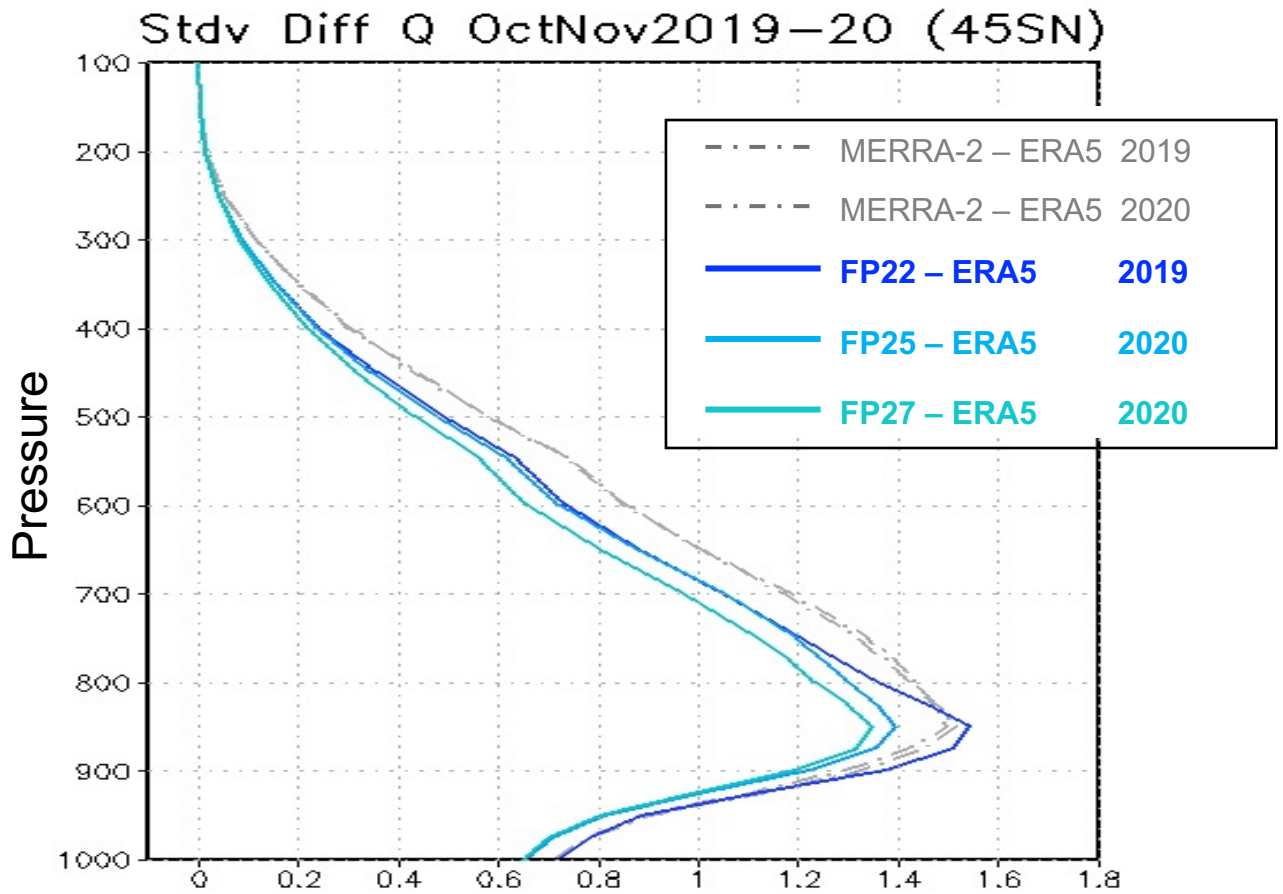


10-year time series of root mean square error (RMSE) of 48-hour forecasts, sampled regularly, and self-verified of global temperature at 700 hPa .The GEOS-FP in blue is compared with NCEP and ECMWF operational products (gray and black, respectively).

Reasons to update retrospective analysis products

- Model and DAS developments lead to improvements in moisture, temperature, land surface fields.

Improvements in the analysis field

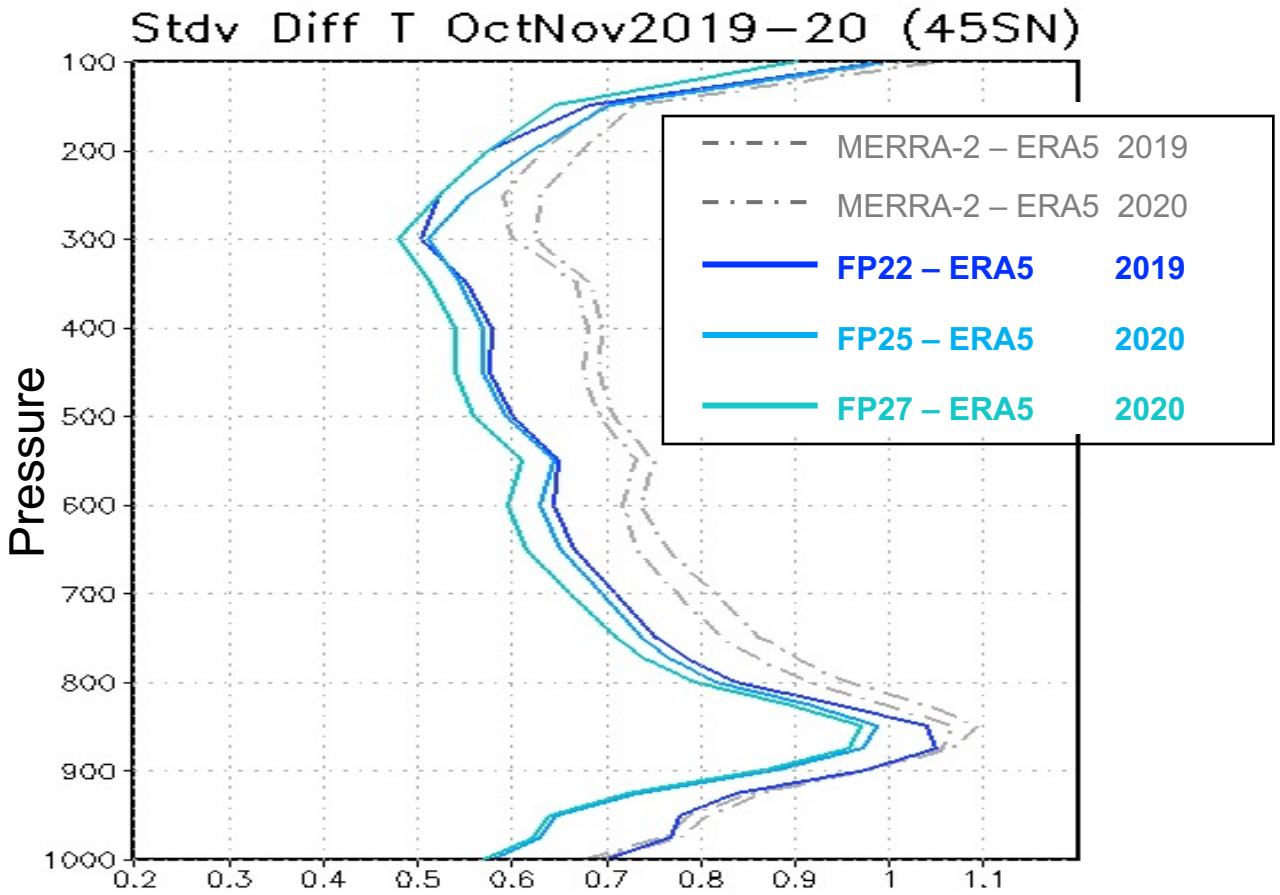


Standard deviation of the difference with ERA5 for the specific humidity (g/kg) for MERRA-2 (grey) and three versions of the FP systems FP22, FP25, FP27 (dark blue, light blue, cyan, respectively)

Reasons to update retrospective analysis products

- Model and DAS developments lead to improvements in moisture, temperature, land surface fields.

Improvements in the analysis field

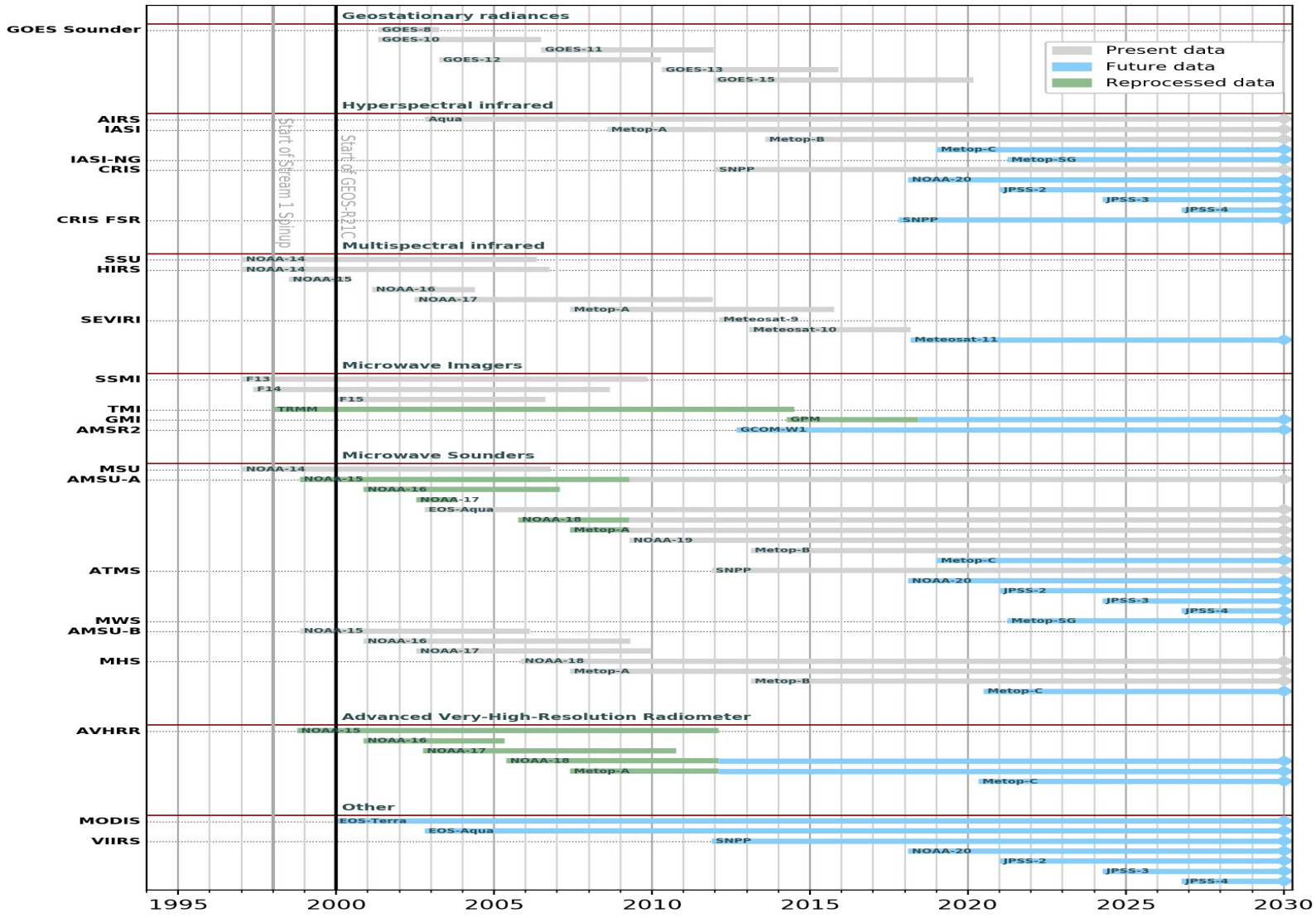


Standard deviation of the difference with ERA5 for the specific humidity (g/kg) for MERRA-2 (grey) and three versions of the FP systems FP22, FP25, FP27 (dark blue, light blue, cyan, respectively)

Reasons to update retrospective analysis products

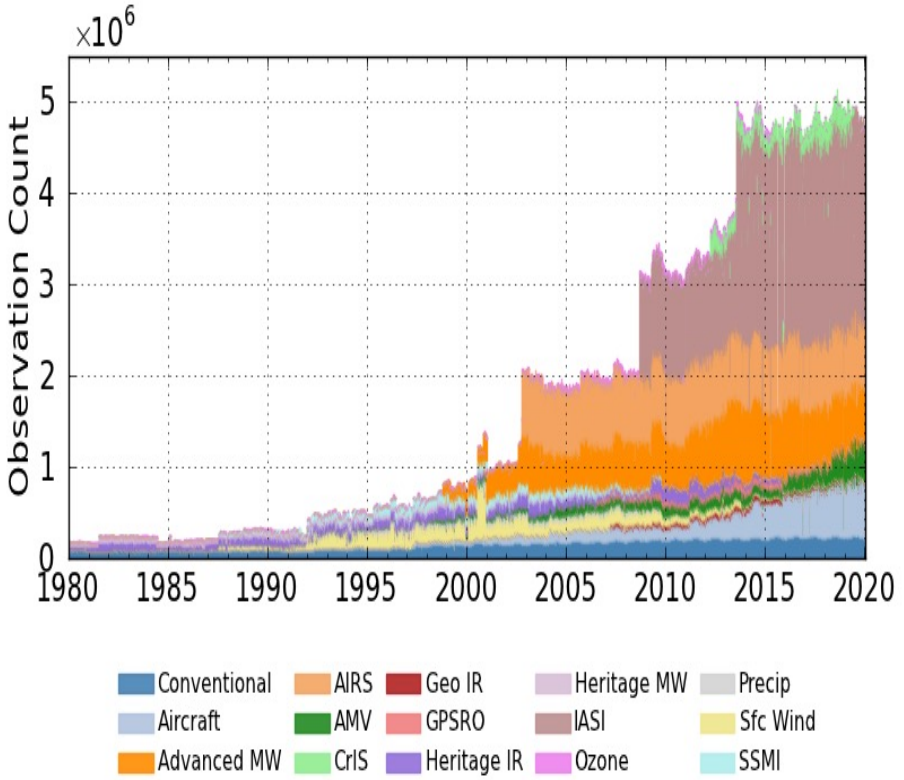
- Opportunity to use **reprocessed** versions of older operational observations. (AMSU-A, AVHRR, AMV, SBUV-2, MLS, COSMIC).
- Opportunity to use **new** data (OMPS-NP, OMPS-NM, COSMIC2, Metop-C, JPSS…)
- Opportunity to use **differently**: All-sky (GMI, TMI, MHS, AMSR-2, AMSR-E)

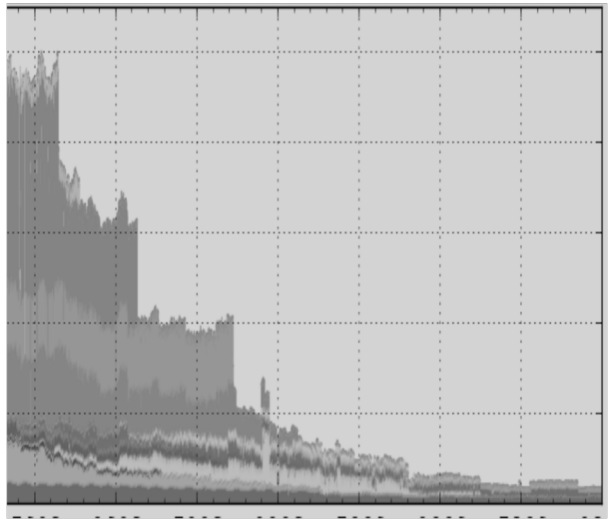
Updated Radiances since MERRA-2



Reasons to update retrospective analysis products

- The ability of older systems to ingest new types of observations is limited. With instrument failures, **they start running out of data.**

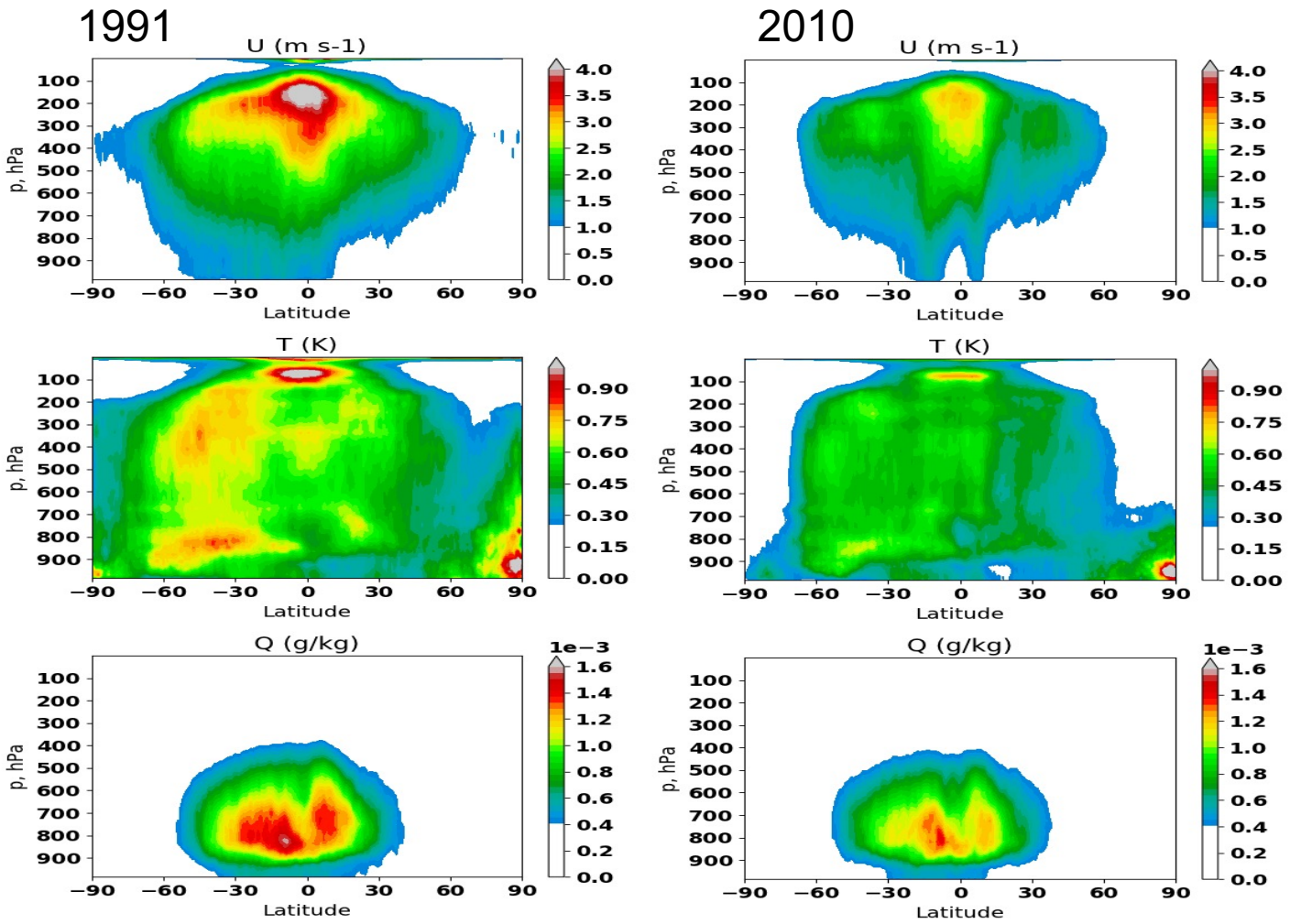




Reasons to update retrospective analysis products

- The ability of older systems to ingest new types of observations is limited. With instrument failures, **they start running out of data.**
- Adequate constraint from data is important.

Standard deviations of the differences between parallel streams during the overlaps of 1991 and 2010



EL Akkraoui et al, 2021

Reasons to update retrospective analysis products

- Older models are harder to maintain

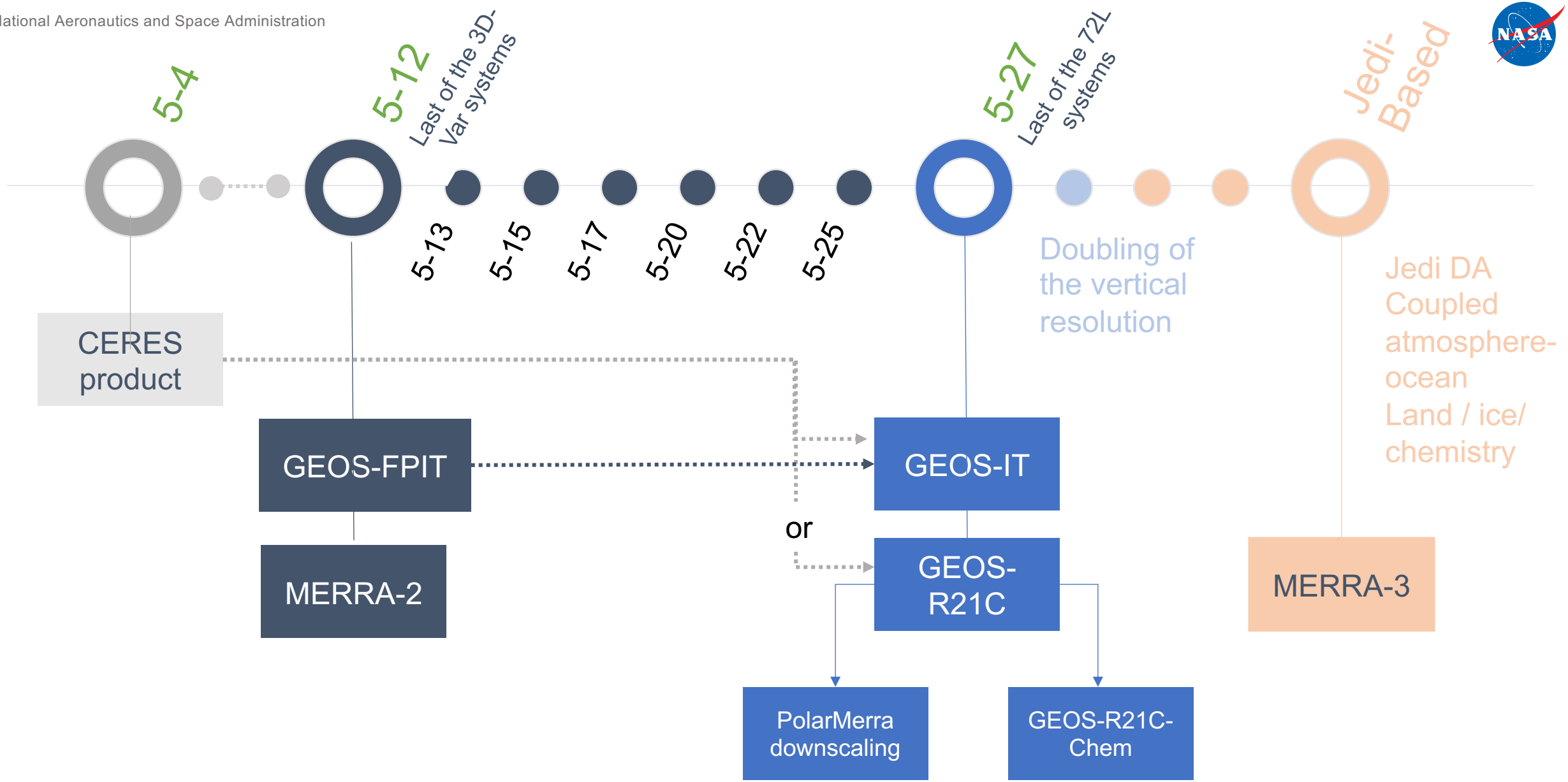
Changes in the hardware/software

(Slurm, SP3, SLES-11, SLES-12 transition!).

Transition from CVS to Git

Some changes affect reproducibility of older systems.

With each change, the operational knobs and scripts have to be upgraded to the new system or retrofitted back to older systems to maintain reproducibility or function.


5-4
5-12
Last of the 3D-Var systems
5-13
5-15
5-17
5-20
5-22
5-25
5-27
Last of the 72L systems
Jedi-Based
Doubling of the vertical resolution
Jedi DA
Coupled atmosphere-ocean
Land / ice/ chemistry
CERES product
GEOS-FPIT
MERRA-2
GEOS-IT
or
GEOS-R21C
PolarMerra downscaling
GEOS-R21C-Chem
MERRA-3

Configuration

GEOS-FPIT	
Target	Atmosphere
Resolution	50km, L72 (C180,L72)
DA	3DVar / Clear-sky
Version	GEOSadas-5.12
Period	2000-onwards
Obsys	MERRA-2 (no MLS)

Upgraded model and observing system

GEOS-IT	
Target	Atmosphere
Resolution	50km, L72 (C180,L72)
DA	3DVar / Clear-sky
Version	GEOSadas-5.27 – NLv3
Period	2000-onwards
Obsys	New/reprocessed (No MLS, No OMPS-LP)

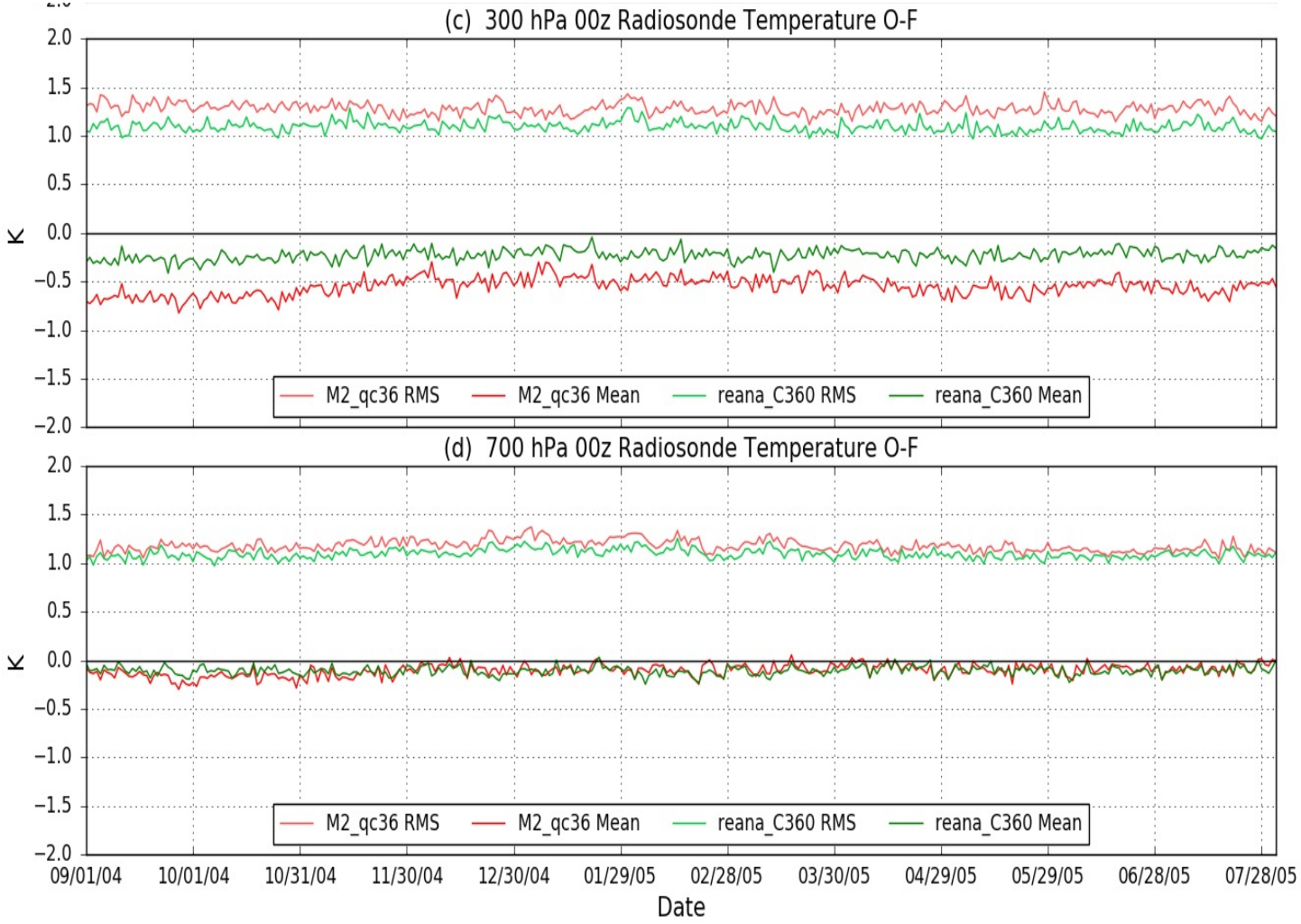
MERRA-2	
Target	Atmosphere
Resolution	50km, L72 (C180,L72)
DA	3DVar / Clear-sky
Version	GEOSadas-5.12
Period	1980-onwards
Obsys	MERRA-2

Upgraded model, data assimilation, observing system, And horizontal resolution

GEOS-R21C	
Target	Atmosphere
Resolution	25km, L72 (C360,L72)
DA	Hybrid 4DEnVar / All-sky
Version	GEOSadas-5.27 – NLv3
Period	2000-onwards
Obsys	New/reprocessed

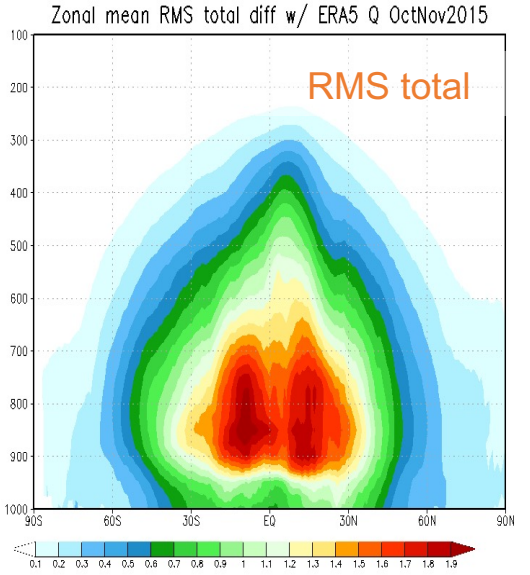
Preliminary results from Prototype-R21C

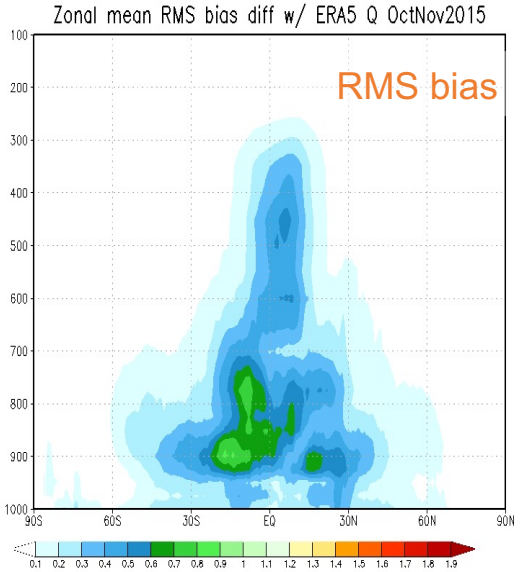
- Improvements in the output agreement with radiosonde data

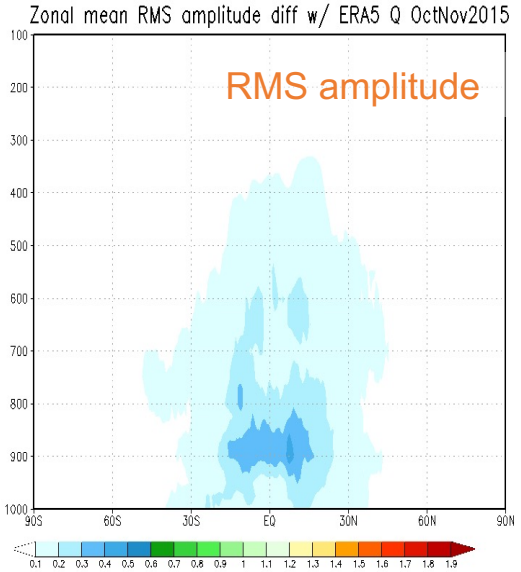


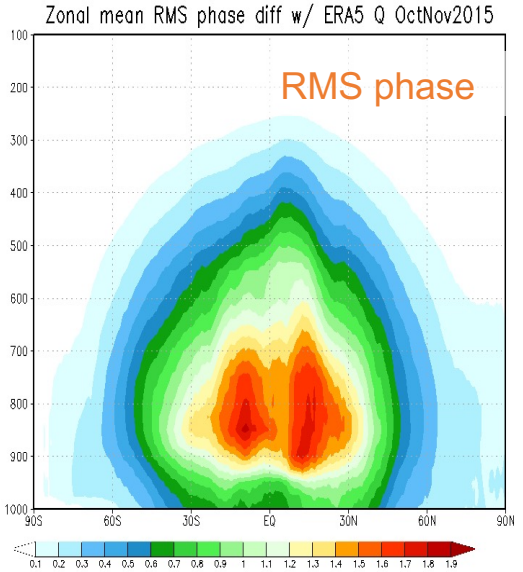
RMS Difference with ERA5 – Specific Humidity

MERRA-2









$$\mathrm{MSE_{TOT}} = \mathrm{MSE_{BIAS}} + \mathrm{MSEAMPL} + \mathrm{MSEPHAZ}$$

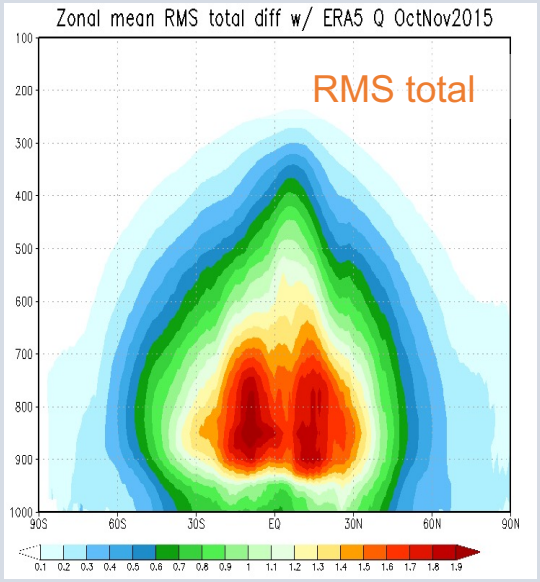
$$\mathrm{MSE_{BIAS}} = (\bar{X} - \bar{Y})^2$$

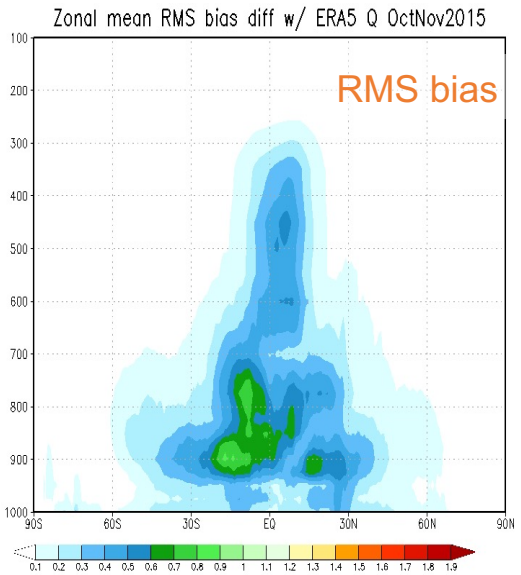
$$\mathrm{MSE_{AMPL}} = \left(\sigma(X) - \sigma(Y)\right)^2$$

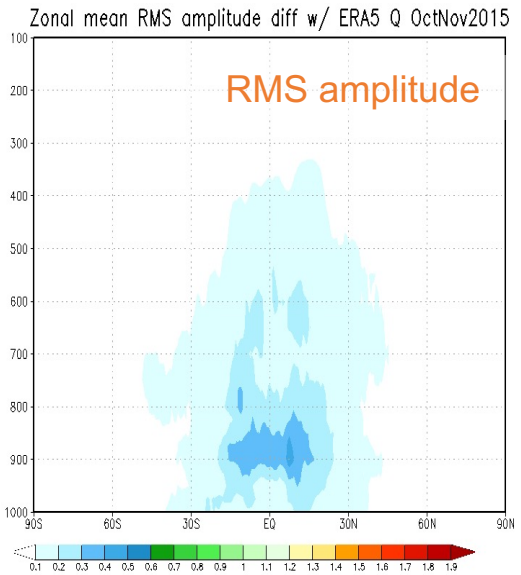
$$\mathrm{MSE_{PHAZ}} = 2\,(1-\rho)\,\sigma(X)\sigma(Y)$$

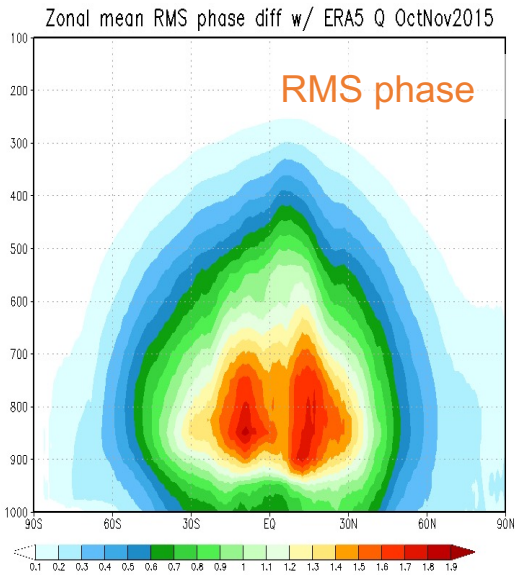
RMS Difference with ERA5 – Specific Humidity

MERRA-2

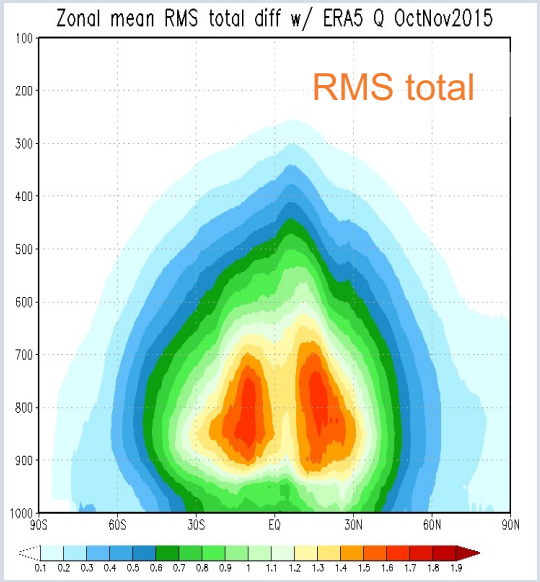


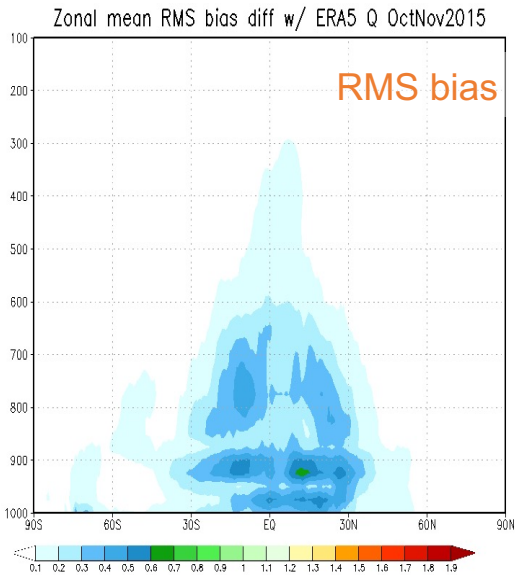


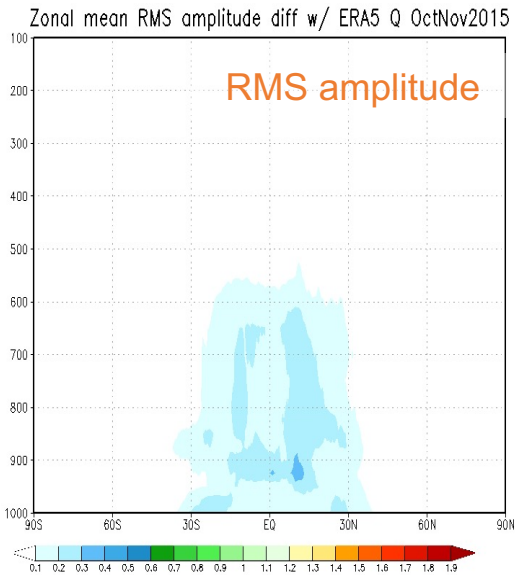


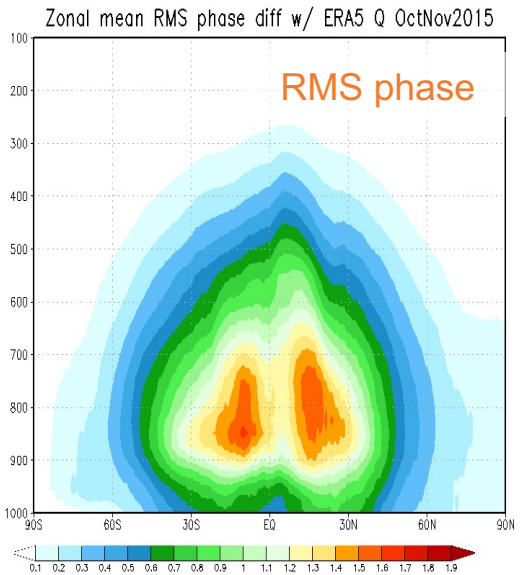


Prototype-R21C



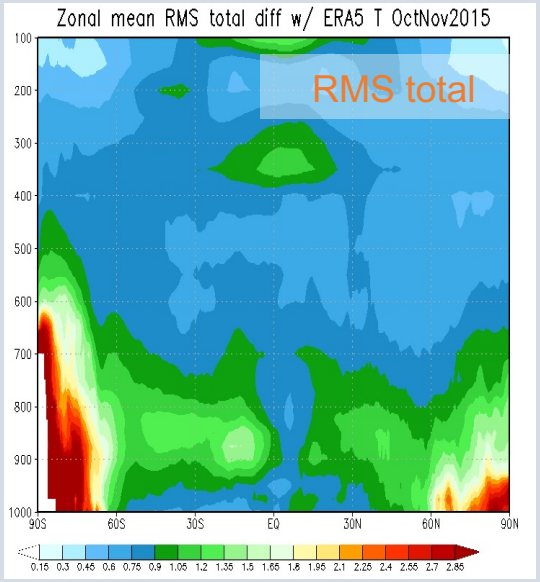


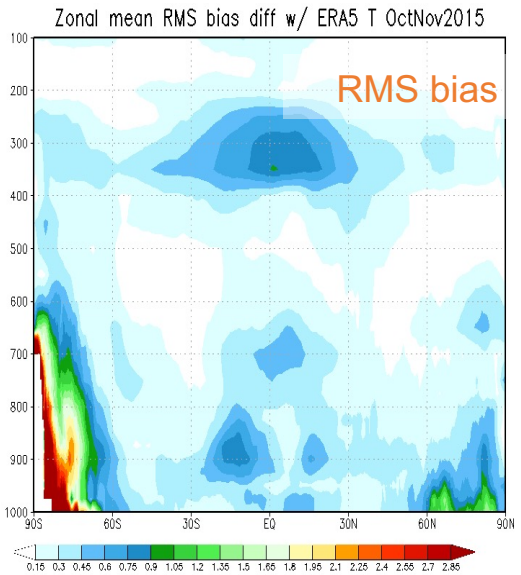


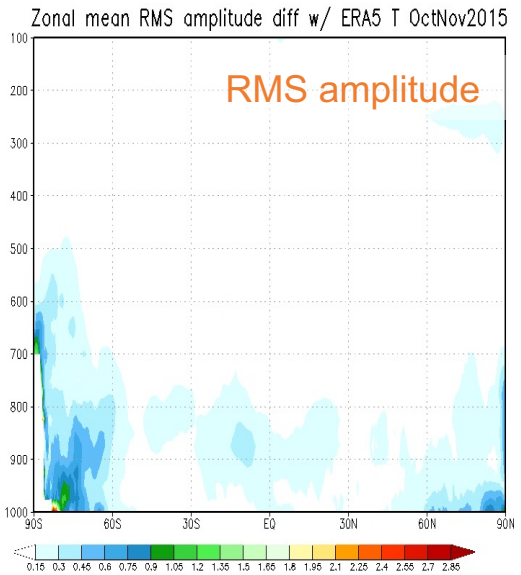


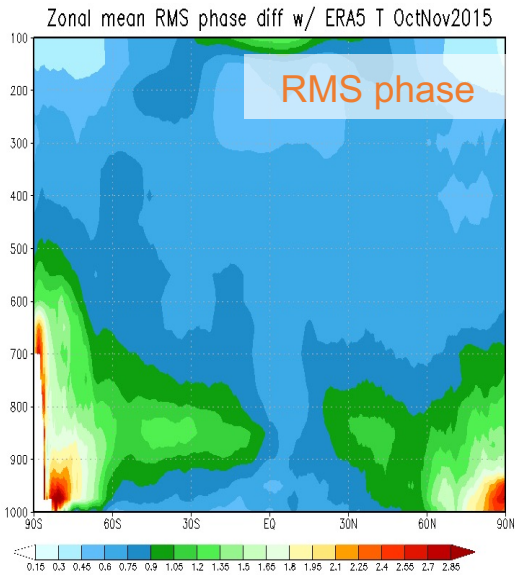
RMS Difference with ERA5 – Temperature

MERRA-2

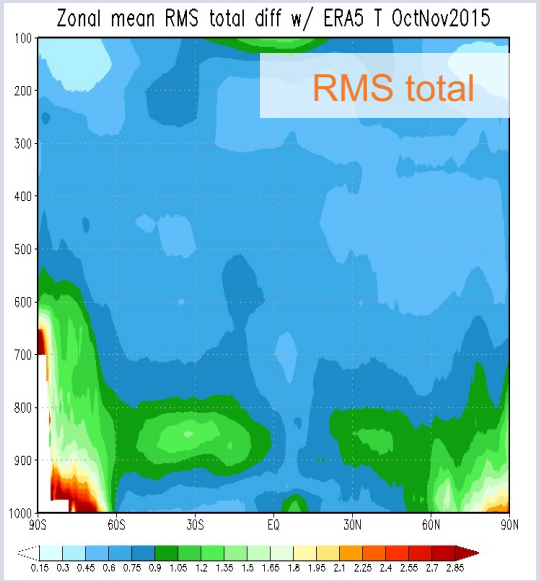


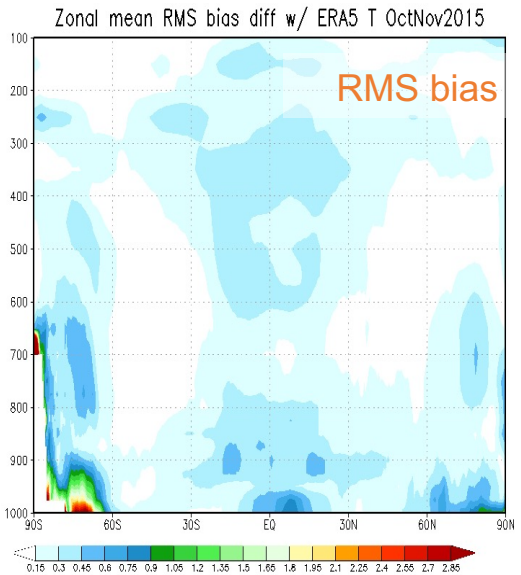


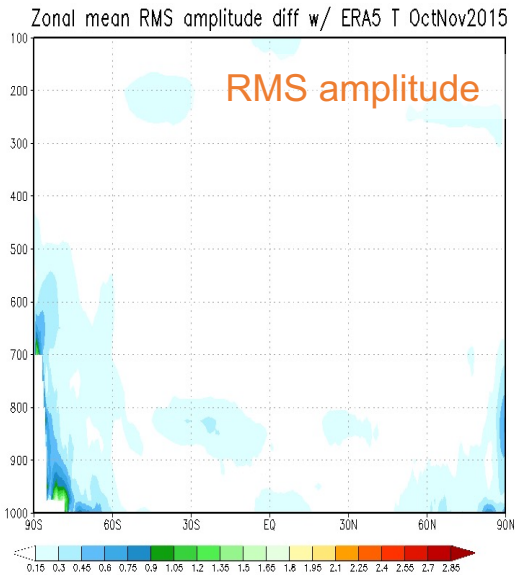


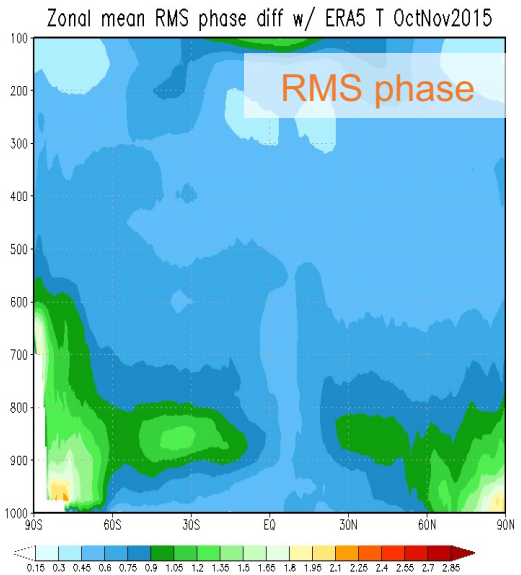


Prototype-R21C









Summary

- The GMAO is preparing to produce two retrospective products bridging the gap from NASA's EOS observations to the post-EOS observations: GEOS-IT for the instrument teams and GEOS-R21C for reanalysis research applications.
- Build on the advances in modeling and data assimilation introduced into GEOS-FP since MERRA-2.
- Opportunity to use upgraded observing system.
- The GEOS-IT is planned as a replacement to the current GEOS-FPIT.
  - Production team is working on a sample data to be validated internally and shared with FPIT users for further validation.
- The GEOS-R21C is planned as a stepping-stone towards the decadal goal of producing MERRA-3, an integrated Earth System reanalysis, coupling atmosphere, ocean, land and ice.
  - Preliminary test results with a prototype-R21C are encouraging.
  - On-going work: dry-mass conservation, land-ice mask in OSTIA boundary conditions, use of IMERG product for the observation-corrected model precipitation, production stream strategy.